Optimization as a guide:

Identifying Promising Integrated Solutions Water Management for California

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Purposes of screening models

Quickly, inexpensively,

Suggest promising alternatives for more detailed consideration & analysis.

Avoid getting bogged down in details at the beginning.

Help figure out future analysis.

Broad screening objectives

a) Lay out the big picture

b) Which strategies seem to go well together? As a big picture, what could the future look like?

c) How can we do better in the future? (in management, in analysis)

d) What analysis limitations should be considered as we move beyond screening analysis?

e) Some future directions for policy & analysis.

Some practical concerns

1) Inexpensive
2) Readily available and fairly quick
3) Documented
4) Documented limitations
5) Interpretable insights
6) Trusted some
7) Addresses some major planning concerns

Giving some perspective

"The night is dark, the wind howls, the tempest rages. But with morning comes light, and calm, and the hope of making harbor in safety; for the rising sun, as it vanquishes the darkness, frees men's minds too from the grip of fear."

Camoens, The Lusiads (1572)

Screening models are to put things in perspective.

Climate changes in California

- Historical Droughts
- Historical climate variability (ENSO, PDO, …)
- Paleo-droughts
- Sea level rise
- Climate warming
- Other form of climate change?

Climate Warming and Water Supply Management

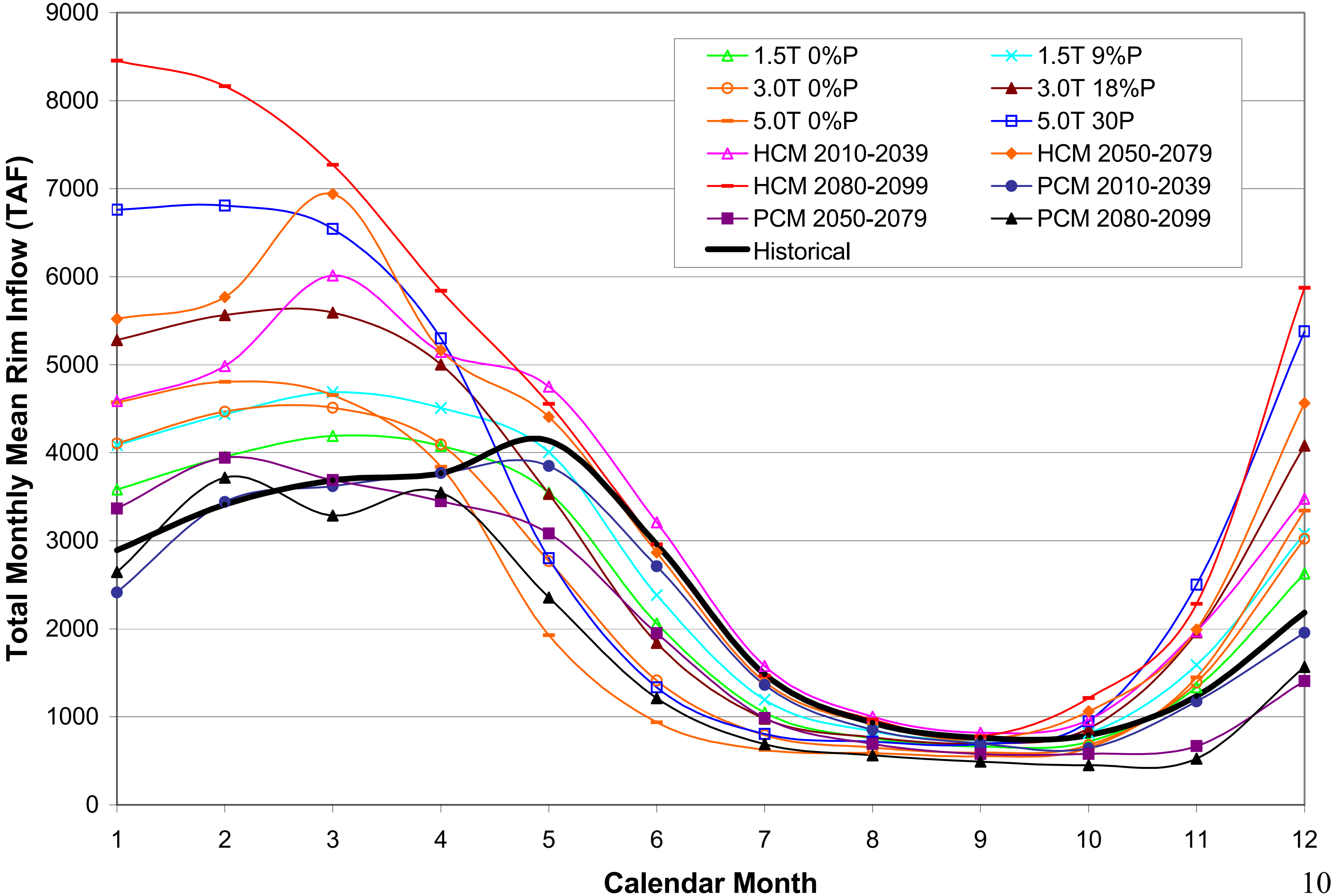
- Preliminary study of climate warming for water management in California
- 2100 climate warming <u>and</u> population growth scenarios
- CALVIN model identifies promising adaptations to climate and population changes
- Preliminary results

Thanks to California Energy Commission!

2100 Climate Warming

1. Water availability changes estimated for 12 climate warming scenarios (based on LBNL).
2. Water supply impacts estimated for:
   a. Major mountain inflows
   b. Groundwater inflows
   c. Local streams
   d. Reservoir evaporation
3. Effects estimated for 113 inflows distributed throughout California

2100 Climate Warming



2100 Population & Land Use

1. Future population and land use will greatly affect water demands.
2. With growth to 92 million (UCB), urban demands grow by ~ 7.2 maf/yr
3. Urbanization of irrigated land reduces agricultural demands by ~ 2.7 maf/yr
4. Net effect is big (+4.5 maf/yr) and economically important

Integrated Adaptation Options

- Water allocation (markets & exchanges)
- System operations
  - Conjunctive use
  - Coordinated operations
- Urban conservation/use efficiencies
- Cropping changes and fallowing
- Agricultural water use efficiencies
- New technologies
  - Wastewater reuse
  - Seawater desalination

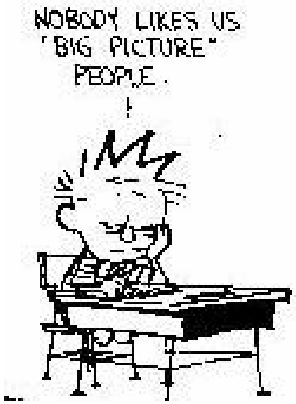
Motivation for CALVIN

- California's water system is huge and complex.
- Water is controversial and economically important.
- Major changes are being considered.

- Can we make better sense of this system?
  – Understanding from data and analysis
  – Insights from results
  – Reduce reliance on narrow perspectives
- How could system management be improved?
- What is economic value of additional water and changes in facilities & policies?

These are not "back of the envelope" calculations.

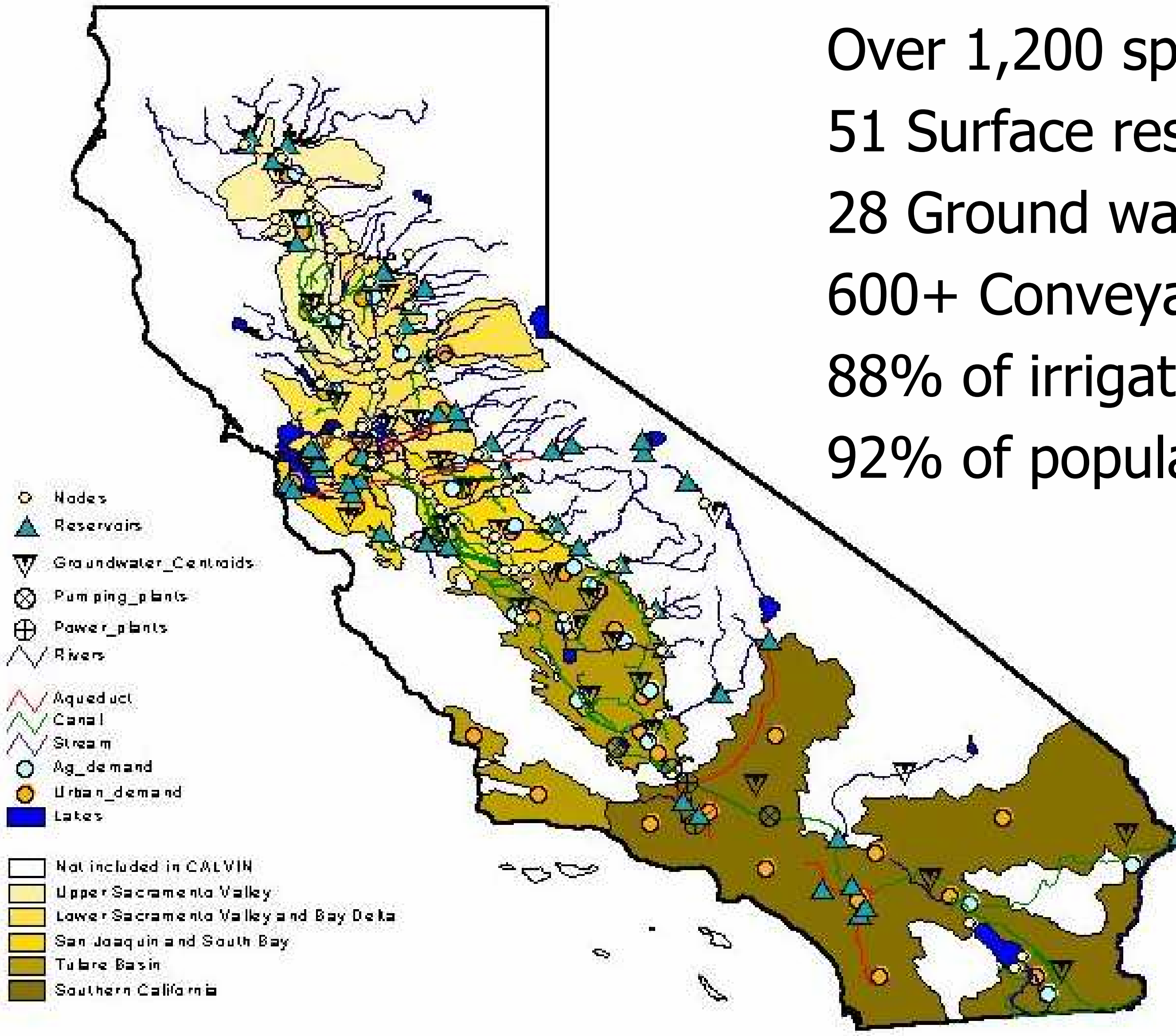
What is CALVIN?



- Model of entire inter-tied California water system
- Surface <u>and</u> groundwater systems; supply <u>and</u> demands
- Economics-driven <u>optimization</u> model
  - Economic Values for Agricultural, Urban, & Hydropower Uses
  - Flow Constraints for Environmental Uses
- Prescribes monthly system operation over a 72-year representative hydrology

Maximizes economic performance within constraints

CALVIN's Spatial Coverage



Over 1,200 spatial elements

51 Surface reservoirs

28 Ground water reservoirs

600+ Conveyance Links

88% of irrigated acreage

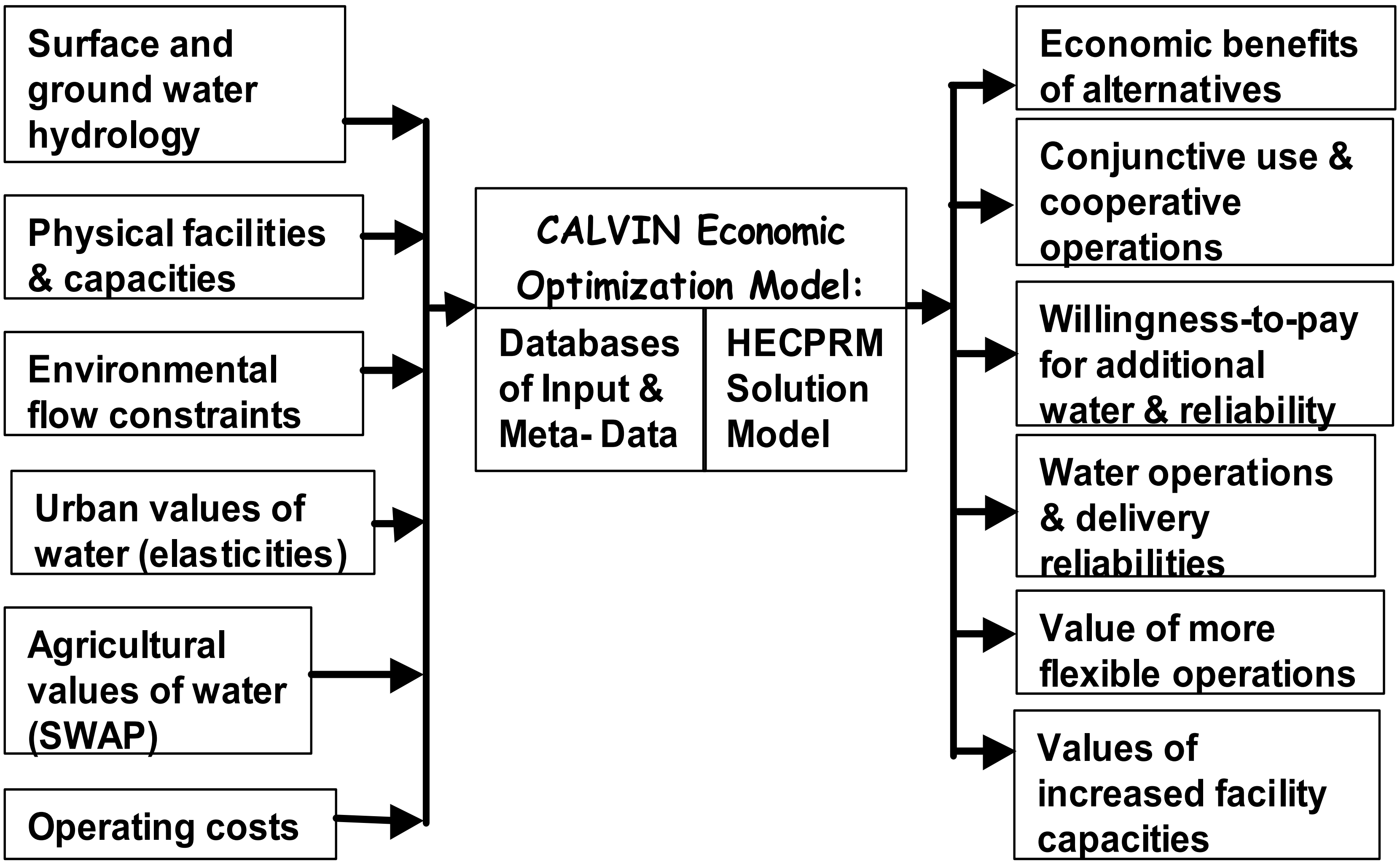
92% of population

Economic Values for Water

- Agricultural: Production model SWAP
- Urban: Demand model based on price elasticities
- Hydropower
- Operating Costs: Pumping, treatment, water quality, etc.

Environmental flows and deliveries as <u>constraints</u> – with first priority

Data Flow for the CALVIN Model



Database and Interface

- Tsunami of data for a controversial system
  - Political need for transparent analysis
  - Practical need for efficient data management
- Databases central for modeling & management
- Data documentation!
- Database & study management software
- Planning & modeling implications

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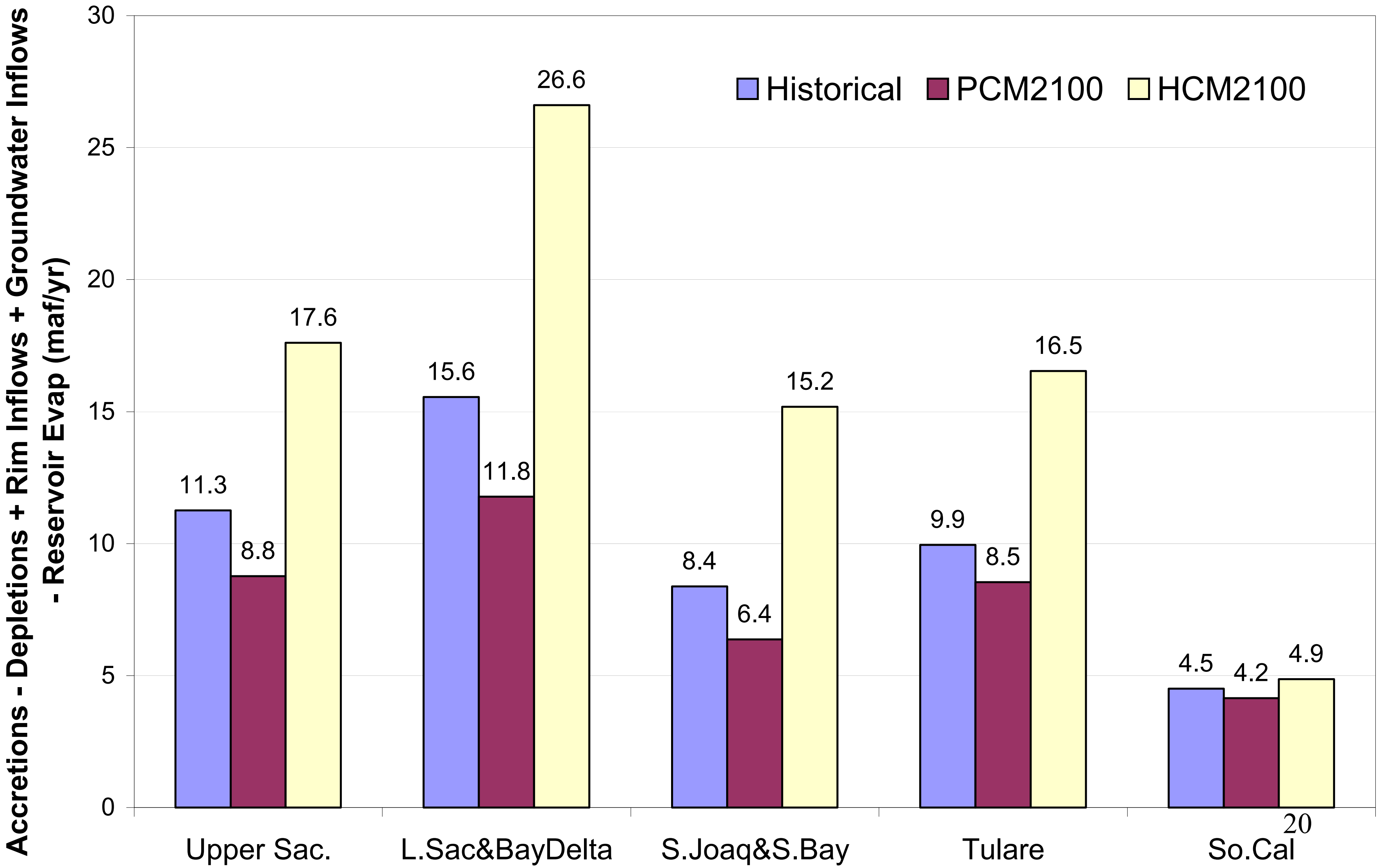
Climate Scenarios by Region



Alternative Conditions

1) Base 2020 – Current policies for 2020
2) SWM 2020 – Statewide water market 2020
3) SWM 2100 – SWM2020 with 2100 demands
4) PCM 2100 – SWM2100 with dry warming
5) HCM 2100 – SWM2100 with wet warming

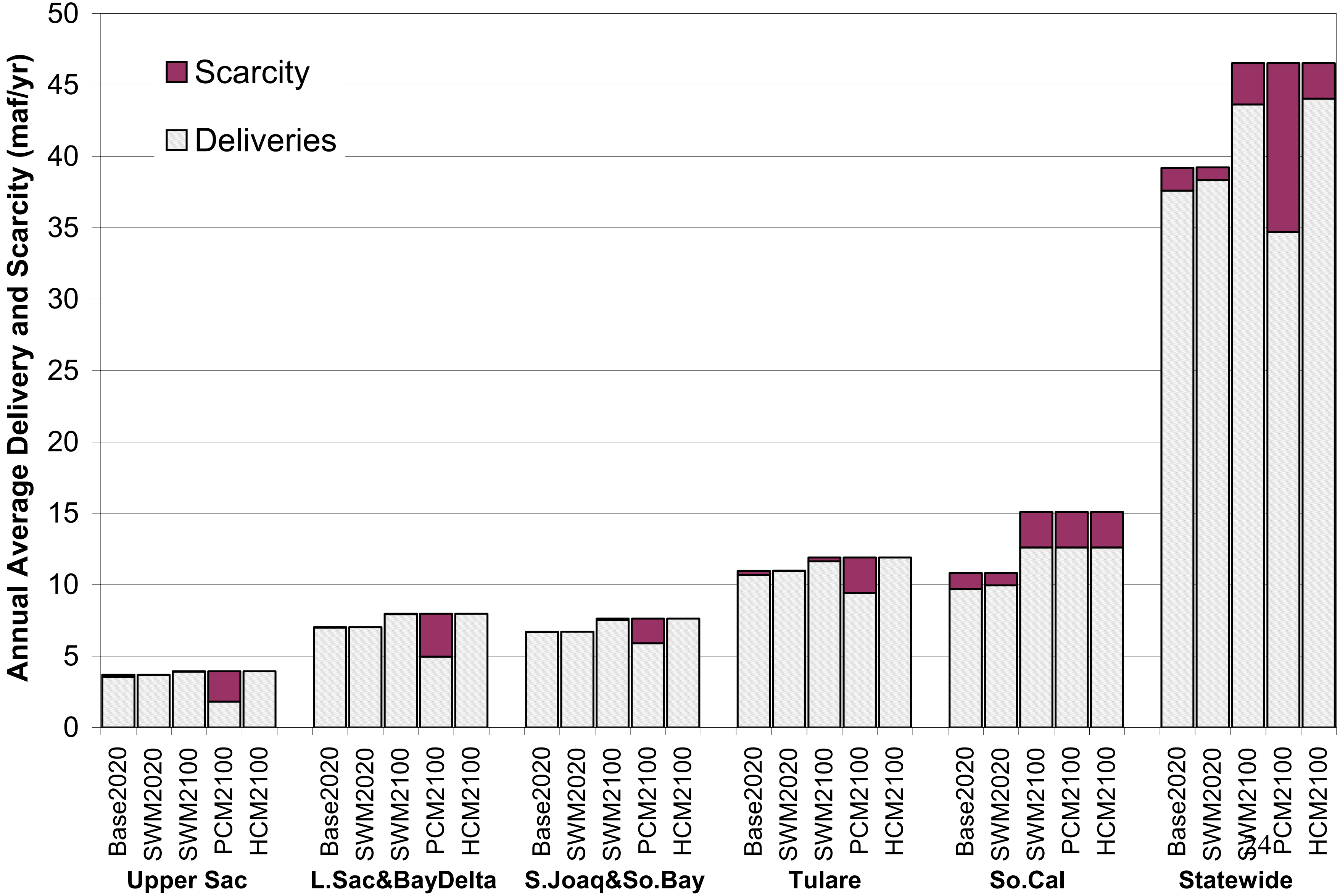
Some Early Results

- Delivery, Scarcity, and Economic Performance
- Conjunctive Use and other Operations
- New Technologies
- Costs of Environmental Flows
- Flood Frequency
- Hydropower Performance
- Economic Value of Facility Changes

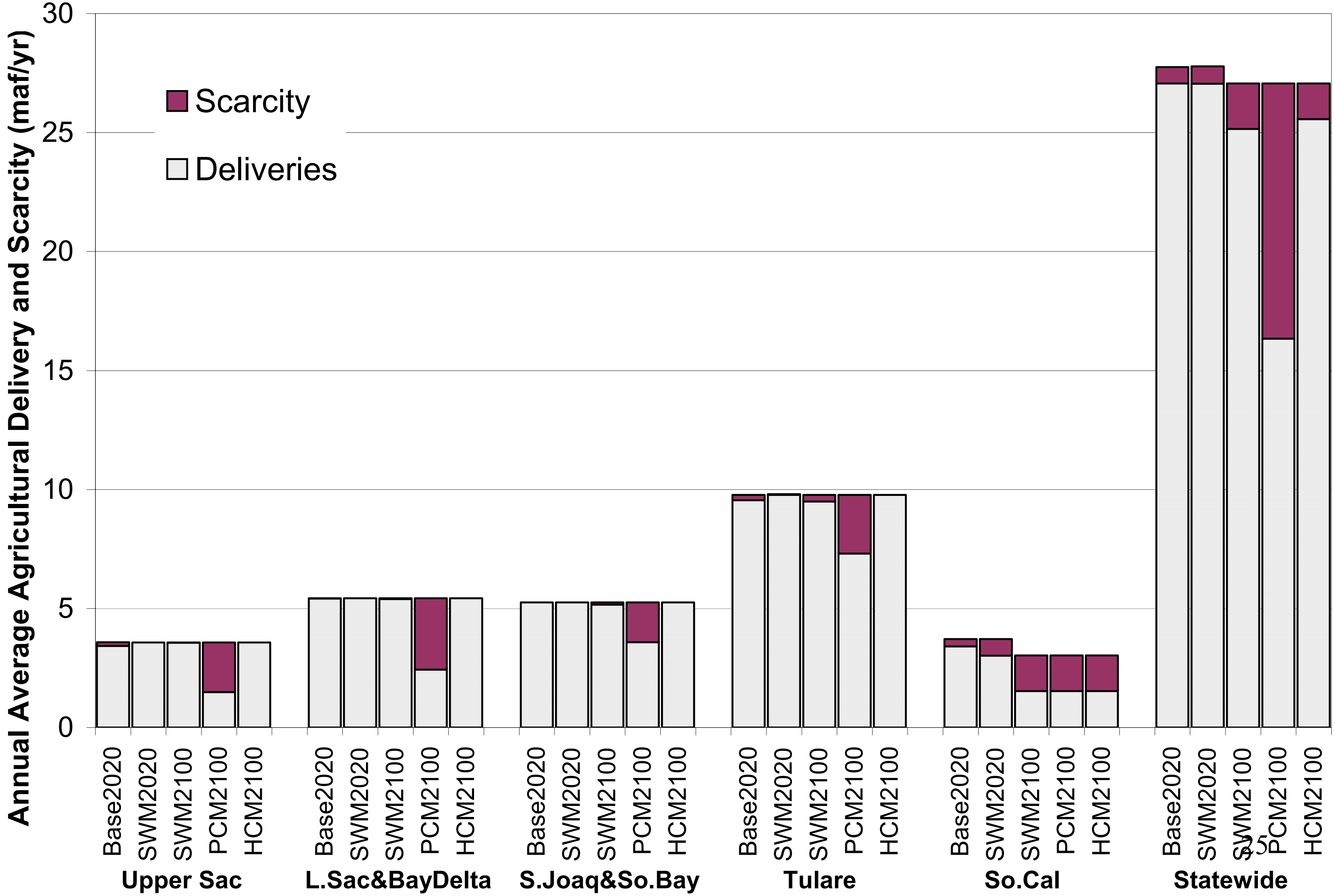
Scarcity, Operating, & Total Costs
($ million/yr)

Cost	Base 2020	SWM 2020	SWM 2100	PCM 2100	HCM 2100
Urban Scarcity	1,564	170	785	872	782
Agric. Scarcity	32	29	198	1,774	180
Operating	2,581	2,580	5,918	6,065	5,681
Total Costs	**4,176**	**2,780**	**6,902**	**8,711**	**6,643**

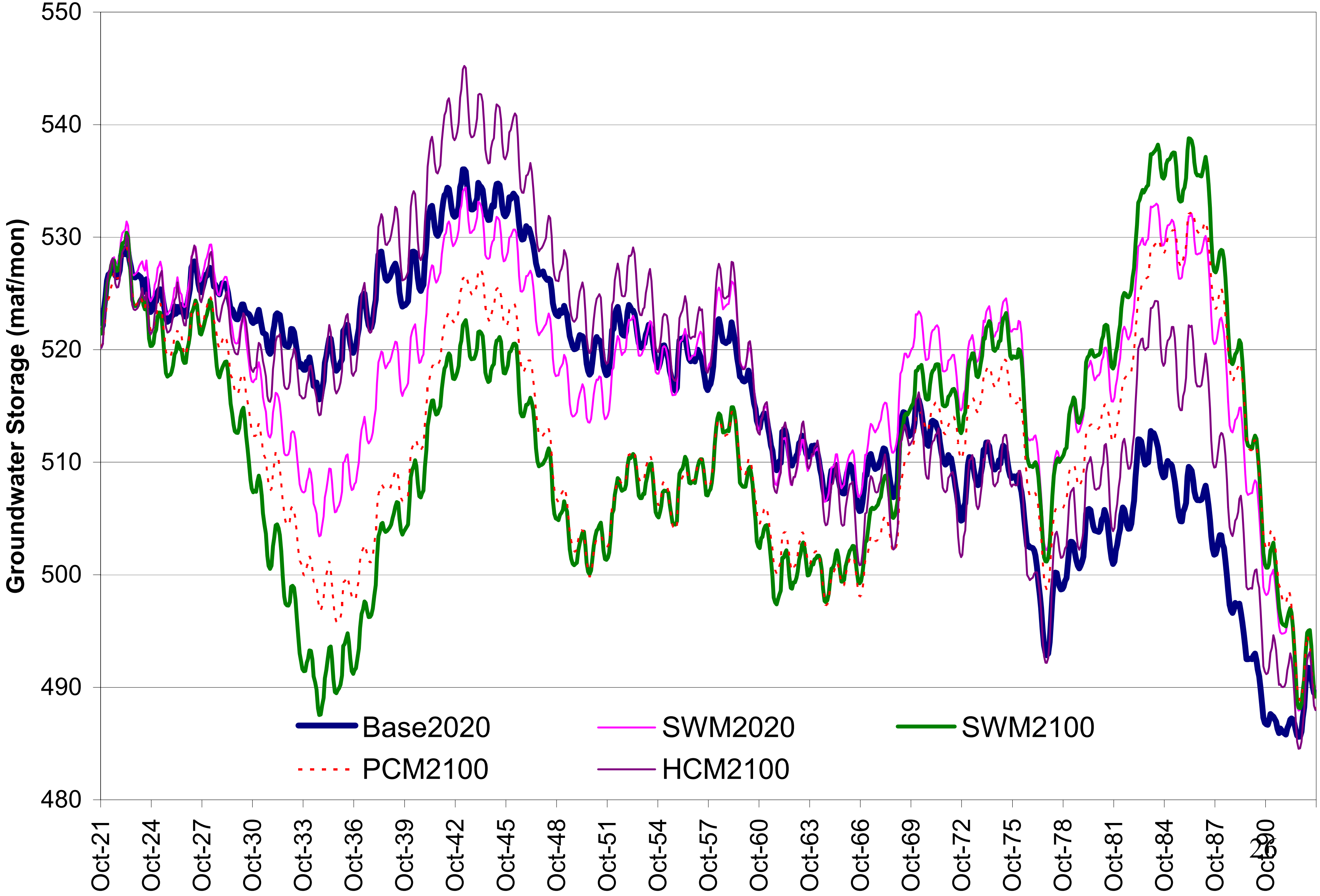
Total Deliveries and Scarcities



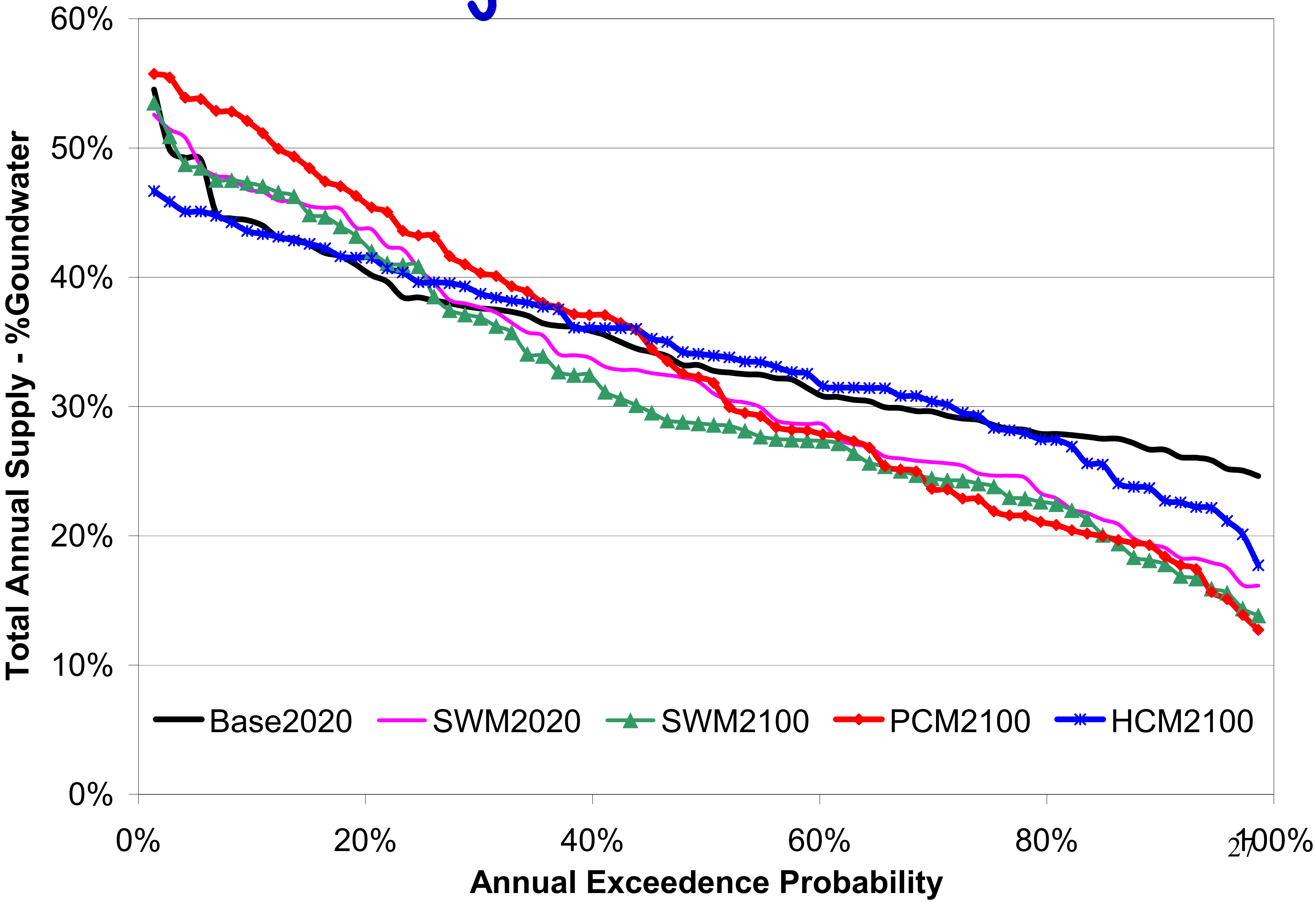
Agricultural Deliveries & Scarcities



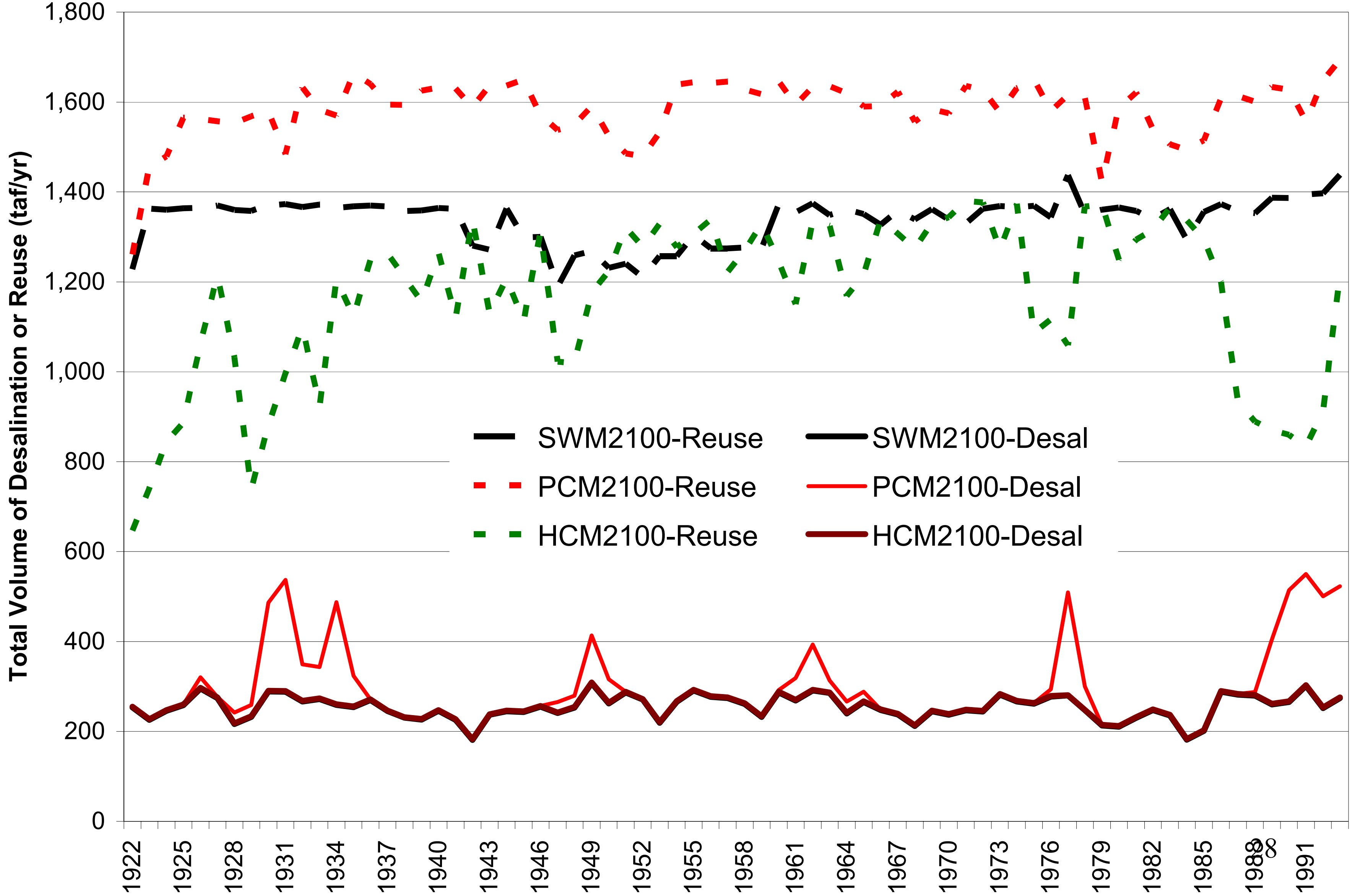
Groundwater Operations



Conjunctive Use



New Source Technologies



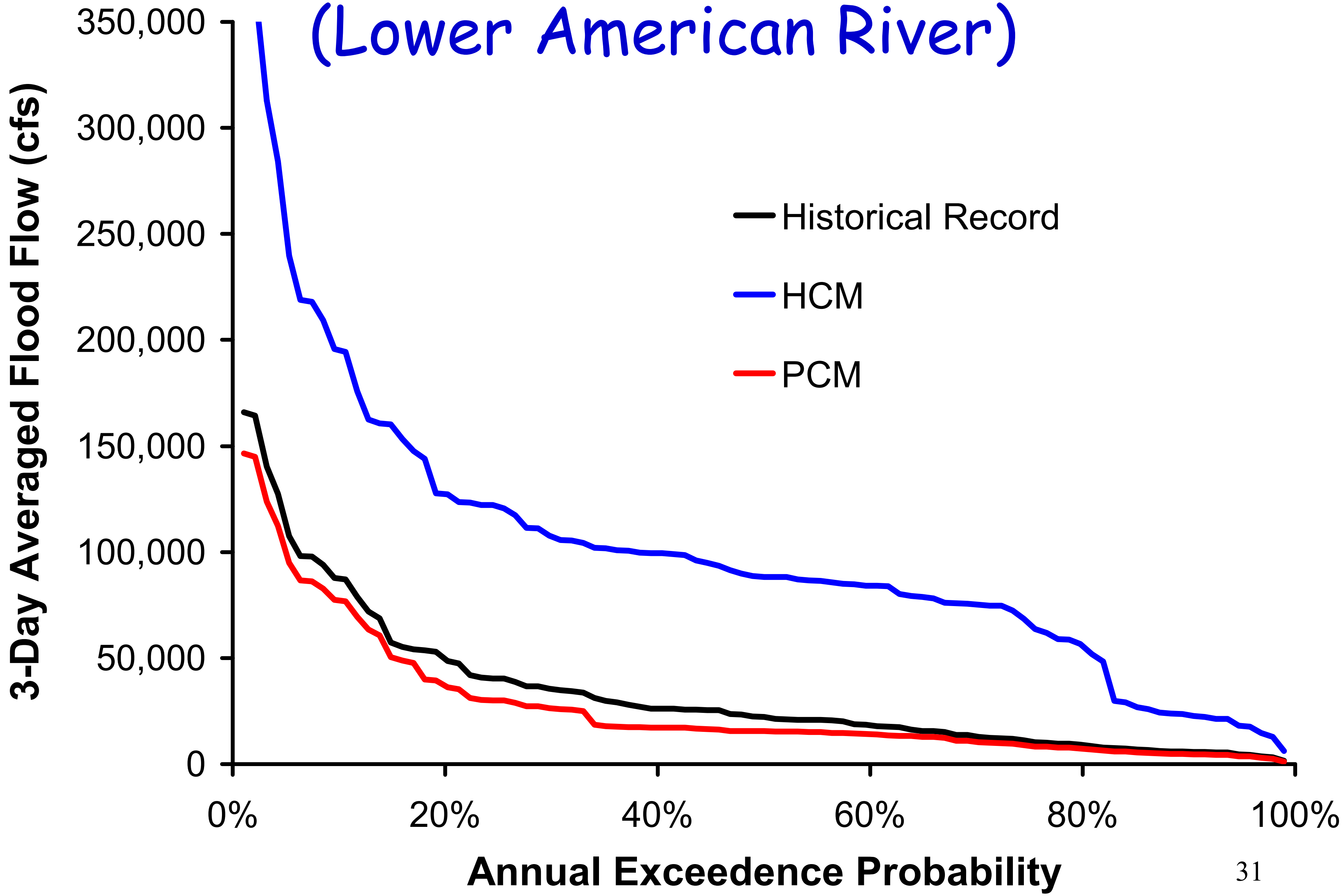
Environmental Flow Costs

Minimum Instream Flows	Average WTP ($/af) SWM2020	SWM2100	PCM2100	HCM2100
Trinity River	0.6	45.4	1010.9	28.9
Sac. R. at Keswick	0.1	3.9	665.2	3.2
Mokelumne River	0.1	20.7	332.0	0.0
Yuba River	0.0	0.0	1.6	1.0
Merced River	0.7	16.9	70.0	1.2
Mono Lake Inflows	819.0	1254.5	1301.0	63.9
Owens Lk. Dust Mitigation	610.4	1019.1	1046.1	2.5
Refuges				
Sac West Refuge	0.3	11.1	231.0	0.1
SJ/Mendota Refuges	14.7	32.6	249.7	10.6
Pixley Refuge	24.8	50.6	339.5	12.3
Kern refuge	33.4	57.0	376.9	35.9
Delta Outflow	**0.1**	**9.7**	**228.9**	**0.0**

Economic Value of Facility Changes
($/unit-yr)

Surface Reservoir (taf)	SWM2100	PCM	HCM
Turlock Reservoir	69	202	56
Santa Clara Aggregate	69	202	56
Pardee Reservoir	68	202	56
Pine Flat Reservoir	66	198	56
New Bullards Bar Reservoir	65	196	56
Conveyance (taf/mo)			
Lower Cherry Creek Aqueduct	7886	8144	7025
All American Canal	7379	7613	6528
Putah S. Canal	7378	7611	6528
Mokelumne Aqueduct	7180	7609	6301
Coachella Canal	3804	3487	3618
Colorado Aqueduct	1063	970	759
California Aqueduct	669	1823	452

Annual Flood Frequency
(Lower American River)



Screening Result Conclusions

1) Multiple water management options can be coordinated to great effect for all scenarios.
2) Integrated analysis is possible and insightful.
3) Future water demands matter! Similar magnitude to climate warming effects.
4) Must allow future adaptations – Optimization should include many options.
5) California's system can adapt, at some cost.

Conclusions from Results (con't)

6) Central Valley agriculture sensitive to dry warming
7) Urban S. Calif. less sensitive to warming
8) Flooding problems
9) Adaptation would be challenging
   Institutional flexibility needed to respond to both population and climate changes.
10) Study has limitations. But some promising and robust management and policy suggestions are identified.

Overall Conclusions

1) Screening models:

- Allow big picture integration and perspective
- Allow integrated options to be explored
- Provide some useful insights
- Need detailed analysis to follow

2) Optimization is the only sane way to explore hugely complex systems with millions of local options and conditions.

OK, one more conclusion…

3) CALVIN illustrates significant new capabilities:
   a) Statewide and regional analysis
   b) Integrated economic and engineering views
   c) Explicitly integrated options and operations
   d) Documentation of data and model
   e) Suggests new management options
   f) Take the good, but remember the limitations.

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